REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
02 Feb 2015

2. REPORT TYPE
Journal Article

3. DATES COVERED *(From – To)*
Sep 2001 – Dec 2010

4. TITLE AND SUBTITLE
A Review of the First 10 Years of Critical Care Aeromedical Transport During Operation Iraqi Freedom and Operation Enduring Freedom The Importance of Evacuation Timing

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Nichole Ingalls, MD, MPH; David Zonies, MD, MPH; Jeffrey A. Bailey, MD; Kathleen D. Martin, MSN, RN, CCRN; Bart O. Iddins, MD, DVM; Paul K. Carlton, MD; Dennis Hanseman, PhD; Richard Branson, MSc; Warren Dorlac, MD; Jay Johannigman, MD

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USAF School of Aerospace Medicine
Aeromedical Research Department
2510 Fifth St.
Wright-Patterson AFB, OH 45433-7913

8. PERFORMING ORGANIZATION REPORT NUMBER
AFRL-SA-WP-JA-2013-0037

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution A: Approved for public release; distribution is unlimited. Case Number: 88ABW-2013-3197, 10 Jul 2013

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Advances in the care of the injured patient are perhaps the only benefit of military conflict. One of the unique aspects of the military medical care system that emerged during Operation Iraqi Freedom and Operation Enduring Freedom has been the opportunity to apply existing civilian trauma system standards to the provision of combat casualty care across an evolving theater of operations. To identify differences in mortality for soldiers undergoing early and rapid evacuation from the combat theater and to evaluate the capabilities of the Critical Care Air Transport Team (CCATT) and Joint Theater Trauma Registry databases to provide adequate data to support future initiatives for improvement of performance. Retrospective review of CCATT records and the Joint Theater Trauma Registry from September 11, 2001, to December 31, 2010, for the in-theater military medicine health system, including centers in Iraq, Afghanistan, and Germany. Of 2899 CCATT transport records, those for 975 individuals had all the required data elements. Rapid evacuation by the CCATT. Survival as a function of time from injury to arrival at the role IV facility at Landstuhl Regional Medical Center. The patient cohort demonstrated a mean Injury Severity Score of 23.7 and an overall 30-day mortality of 2.1%. Mortality en route was less than 0.02%. Statistically significant differences between survivors and decedents with respect to the Injury Severity Score (mean[SD], 23.4 [12.4] vs 37.7 [16.5]; $P < .001$), cumulative volume of blood transfused among the patients in each group who received a transfusion ($P < .001$), worst base deficit (mean [SD], −3.4 [5.0] vs −7.8 [6.9]; $P = .02$), and worst international normalized ratio (median [interquartile range], 1.2 [1.0-1.4] vs 1.4 [1.1-2.2]; $P = .03$) were observed. We found no statistically significant difference between survivors and decedents with respect to time from injury to arrival at definitive care. Rapid movement of critically injured casualties within hours of wounding appears to be effective, with a minimal mortality incurred during movement and overall 30-day mortality. We found no association between the duration of time from wounding to arrival at Landstuhl Regional Medical Center with respect to mortality.

15. SUBJECT TERMS
CCATT, Critical Care, combat casualty, evacuation,

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Richard Branson
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
U	U	U	SAR	8	

Original Investigation

A Review of the First 10 Years of Critical Care Aeromedical Transport During Operation Iraqi Freedom and Operation Enduring Freedom

The Importance of Evacuation Timing

Nichole Ingalls, MD, MPH; David Zonies, MD, MPH; Jeffrey A. Bailey, MD; Kathleen D. Martin, MSN, RN, CCRN; Bart O. Iddins, MD, DVM; Paul K. Carlton, MD; Dennis Hanseman, PhD; Richard Branson, MSc; Warren Dorlac, MD; Jay Johannigman, MD

Invited Commentary

IMPORTANCE Advances in the care of the injured patient are perhaps the only benefit of military conflict. One of the unique aspects of the military medical care system that emerged during Operation Iraqi Freedom and Operation Enduring Freedom has been the opportunity to apply existing civilian trauma system standards to the provision of combat casualty care across an evolving theater of operations.

OBJECTIVES To identify differences in mortality for soldiers undergoing early and rapid evacuation from the combat theater and to evaluate the capabilities of the Critical Care Air Transport Team (CCATT) and Joint Theater Trauma Registry databases to provide adequate data to support future initiatives for improvement of performance.

DESIGN, SETTING, AND PARTICIPANTS Retrospective review of CCATT records and the Joint Theater Trauma Registry from September 11, 2001, to December 31, 2010, for the in-theater military medicine health system, including centers in Iraq, Afghanistan, and Germany. Of 2899 CCATT transport records, those for 975 individuals had all the required data elements.

EXPOSURE Rapid evacuation by the CCATT.

MAIN OUTCOMES AND MEASURES Survival as a function of time from injury to arrival at the role IV facility at Landstuhl Regional Medical Center.

RESULTS The patient cohort demonstrated a mean Injury Severity Score of 23.7 and an overall 30-day mortality of 2.1%. Mortality en route was less than 0.02%. Statistically significant differences between survivors and decedents with respect to the Injury Severity Score (mean [SD], 23.4 [12.4] vs 37.7 [16.5]; $P < .001$), cumulative volume of blood transfused among the patients in each group who received a transfusion ($P < .001$), worst base deficit (mean [SD], −3.4 [5.0] vs −7.8 [6.9]; $P = .02$), and worst international normalized ratio (median [interquartile range], 1.2 [1.0-1.4] vs 1.4 [1.1-2.2]; $P = .03$) were observed. We found no statistically significant difference between survivors and decedents with respect to time from injury to arrival at definitive care.

CONCLUSIONS AND RELEVANCE Rapid movement of critically injured casualties within hours of wounding appears to be effective, with a minimal mortality incurred during movement and overall 30-day mortality. We found no association between the duration of time from wounding to arrival at Landstuhl Regional Medical Center with respect to mortality.

JAMA Surg. doi:10.1001/jamasurg.2014.621
Published online June 25, 2014.

Author Affiliations: Author affiliations are listed at the end of this article.

Corresponding Author: Jay Johannigman, MD, Division of Trauma and Critical Care, Department of Surgery, University of Cincinnati, 231 Albert Sabin Way, Mail Location 0558, Cincinnati, OH 45267-0558 (jay.johannigman@uc.edu).

It is an unfortunate truth that advances in the care of the injured patient are perhaps the only benefit of military conflict. The last decade of combat care provided in support of US military operations has witnessed numerous innovations and revisions in the standards of care for the management of injury. These same observations highlight the uniquely synergistic relationship between military and civilian trauma care during past centuries. In the period after the Vietnam War (1970-2000), most of the advances in trauma care, trauma systems, and trauma surgery were attributable to the contributions of the civilian sector.[1] A significant driving force of these advances was the developmental advocacy of the American College of Surgeons' Committee on Trauma (ACS COT) and its trauma review and verification process. Initial system development and structure would be codified by the ACS COT in the foundation document entitled "Resources for Optimal Care of the Injured Patient 2006."[2]

The decade after September 11, 2001 (9/11), witnessed dramatic changes across the American landscape, none more dramatic than the shaping and change undertaken by US military medicine. One of the unique aspects of the military medical care system emerging from and during Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) has been the opportunity to apply existing civilian trauma system standards to the provision of combat casualty care across an evolving theater of operations. Medical operations in support of OIF/OEF represent the first large-scale opportunity for the US military to adapt and incorporate lessons from the civilian trauma system to the combat casualty care arena. This influential transformation was accelerated in part by the presence of a generation of military surgeons who went to war after fellowship training in large, civilian, urban-based trauma centers and systems. Tools such as trauma registries, performance improvement processes, and clinical practice guidelines were familiar instruments to this cadre of fellowship-trained surgeons. These same tools had yet to be incorporated into the US military medical system after the Cold War era. Critical capability shortfalls and significant gaps in care identified by the General Accountability Office and recognized by the military during the first Persian Gulf War led to a significant retooling of most aspects of deployed military medical care during the 1990s and into early 2000.[3-5] Fellowship-trained trauma surgeons successfully advocated and partnered with military medical corps leadership to implement change and incorporate important trauma system principles as advocated by the ACS COT and the optimal resources guidelines. One of the first and perhaps most important products of this advocacy was the military's development of a Joint Theater Trauma System (JTTS).[6] The vision undertaken by military medicine in the initiation of a trauma system of care for the battlefield is summarized in the mission statement of the JTTS: To ensure that each soldier, sailor, airman, and marine injured on the battlefield has the optimal chance for survival and functional recovery.

The joint military medical forces of the United States initiated the development of a combat theater trauma system in early 2004. Initial consultant recommendations included the appointment of a trauma surgeon (JTTS surgeon) at theater medical headquarters to introduce and further develop a theater-wide trauma system. A key component of this early process was the establishment and continued development of the Joint Theater Trauma Registry (JTTR). The JTTR is a data repository to collect and host Department of Defense trauma-related data and is meant to serve as a comprehensive initial database recording demographic, mechanistic, anatomical, physiological, and outcome data for personnel wounded in combat. The form and function of the JTTR were influenced and modeled after the trauma registries developed and implemented by the civilian trauma center community and ACS COT guidelines. Since 9/11, the JTTR has recorded data on more than 10 000 casualties sustaining battle injuries.

The US Air Force (USAF) is doctrinally responsible for the aeromedical evacuation of combat casualties from the theater of operations. Although all 3 services (Army, Navy, and Air Force) were revising their structures and system capabilities for the provision of trauma care, the USAF was simultaneously revising and updating its aeromedical evacuation capabilities. As mobile surgical teams moved forward toward the front line with increasing capabilities, the need to develop the capability to transport stabilized (but not necessarily stable) patients within the aeromedical evacuation system became readily apparent. In response to this need, the USAF created Critical Care Air Transport Teams (CCATTs). The original concept and the CCATTs were developed at the USAF Wilford Hall Medical Center under the leadership of Col J. Christopher Farmer, USAF (retired), Lt Gen Paul K. Carlton Jr, USAF (retired), and many others.

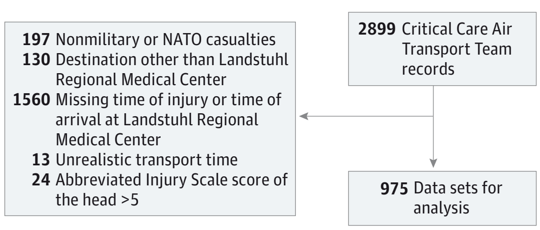
The CCATT is a 3-person team (an intensive care unit [ICU] physician, ICU nurse, and respiratory therapist) with a self-carried equipment set capable of supporting the transport and care of battle-injured patients. The role of the CCATT is to provide ongoing care en route from far-forward locations to more rearward facilities. A CCATT must be capable of providing care for as many as 6 critically ill patients (3 of whom may undergo mechanical ventilation) during aeromedical evacuation transports that may last from 30 minutes to 16 hours or longer. The CCATT concept was developed initially with little precedent experience regarding the movement of critically injured patients across continental distances.[7,8] The initial concept of operation suggested that CCATTs would move patients within 72 to 96 hours of stabilization surgery in the forward area of operations. With growing experience and increasing maturation of theater transport resources, the time to transport patients by CCATT progressively decreased. By the time of the heavy casualty surge during OIF (2004-2006), movement of patients by CCATTs within hours of their field stabilization surgery became increasingly common. Few data and little precedent to provide objective evaluation of the potential benefits of this trajectory of change in CCATT operations existed. An additional challenge was posed by the fact that the data set maintained by CCATTs during transport was handwritten, extremely rudimentary, and lacked sufficient depth to support performance evaluation or improvement.

In this nascent environment, the value of trauma system maturation became apparent. As the JTTR process matured, the ability to provide evidence-based outcome metrics proved invaluable to the formation of clinical practice guidelines and stan-

dards of care for the combat casualty.[9,10] Numerous studies have used the JTTR data, and they have provided a wealth of critical insight into the process, practice, and procedures of care for the injured soldier.[11-13] Members of the CCATT community witnessed this process and hypothesized that the same system improvement effects and potential benefits could be leveraged by applying trauma system metrics and database methods to the movement of CCATT patients. The project described herein was conceived as an attempt to validate the maturity of the CCATT database process. The presented data and analysis mark an initial attempt to bridge the data elements of the CCATT process to the data contained within the JTTR in an effort to establish evidence-based outcome metrics. We chose to test the hypothesis that the time from initial wounding in the combat theater to arrival at the level IV trauma center at Landstuhl Regional Medical Center (LRMC) would affect patient mortality. This hypothesis was developed in an effort to identify patients who may benefit (or be harmed) by early and rapid evacuation. In addition, this initiative was undertaken as a first attempt to evaluate the capabilities of the CCATT and JTTR databases to support future initiatives to improve system performance.

Of note, the military medical system has a different designation for trauma centers than the civilian trauma system. In the military, the role II facility represents the far-forward austere facility where trauma care and initial surgery may be possible. Role III facilities are in theater and offer a more definitive level of resources akin to most level I civilian trauma centers. Role IV facilities in the military are large regional facilities serving major geographic areas and theaters. At present, only 2 military facilities have attained the ACS COT level I designation, and LRMC is one of these military centers.

Figure. Flow of Subjects Through the Study



NATO indicates North Atlantic Treaty Organization.

Methods

The movement of all CCATT patients falls under the command and control of the USAF Air Mobility Command and its Global Patient Movement Requirement Center (GPMRC) located at Headquarters Air Mobility Command, Scott Air Force Base, Illinois. The GPMRC is responsible for matching available USAF cargo and tanker aircraft (C-130, C-17, and KC-135) to the mission of transporting CCATT patients and attendant personnel to the next phase of care.

After approval by the institutional review board of the University of Cincinnati College of Medicine and the US Army Medical Research and Materiel Command, a data request was submitted to the GPMRC for a demographic listing of all patients transported on CCATT missions since 9/11. The unique Social Security identifier from the GPMRC data set was, in turn, used to request a patient data set from the JTTR. These 2 data sets were combined to create a functional registry consisting of patients and outcome data from 9/11 to December 31, 2010. The results matched to the JTTR were queried for a limited subset of the entire JTTR data record. The specific JTTR data points searched were limited to patient demographics, nature and time of wounding, transport times, specific physiological variables, and outcome data.

Results

In total, 2899 CCATT transport records were received from the GPMRC from 9/11 to December 31, 2010. This data set was restricted as shown in the **Figure**. Characteristics of these 975 individuals are summarized in **Table 1**. The typical patient was male, in the US Army, and about 26 years old. The overall 30-

Table 1. Demographics of the 975 Study Participants[a]

Variable	Participant Groups: Entire Data (n = 975)	Survivors (n = 953)	Decedents (n = 22)	P Value
Male sex	961 (98.6)	940 (98.6)	21 (95.5)	.21
Patient category				
Air Force	18 (1.9)	18 (1.9)	0	.93
Army	687 (70.5)	671 (70.4)	16 (72.7)	
Marine	168 (17.2)	164 (17.2)	4 (18.2)	
NATO military	84 (8.6)	82 (8.6)	2 (9.1)	
Navy	18 (1.9)	18 (1.9)	0	
No. of intermediate stops				
1	511 (54.7)	497 (54.5)	14 (63.6)	.58
2	405 (43.4)	398 (43.6)	7 (31.8)	
3	17 (1.8)	16 (1.8)	1 (4.5)	
4	1 (0.1)	1 (0.1)	0	
Age, mean, y	26.0	26.0	26.8	.53

Abbreviation: NATO, North Atlantic Treaty Organization.

[a] Unless otherwise indicated, data are expressed as number (percentage) of particpants. Percentages have been rounded and may not total 100.

Table 2. Injury Characteristics, Resuscitation, and Patient Physiological Features

Variable	All	Survivors	Decedents	*P* Value
ISS, mean (SD)	23.7 (12.7)	23.4 (12.4)	37.7 (16.5)	<.001
Hematocrit level, mean (SD), %	35.2 (8.7)	35.1 (8.6)	37.6 (12.1)	.41
Base deficit, mean (SD), mEg/L	−3.5 (5.1)	−3.4 (5.0)	−7.8 (6.9)	.02
Heart rate, mean (SD), beats/min	107.9 (26.7)	107.9 (26.9)	105.8 (21.4)	.71
SBP, mean (SD), mm Hg	119.0 (26.7)	119.3 (26.0)	108.3 (47.9)	.31
Crystalloid volume, median (IQR), mL	4250 (1967-7540)	4250 (1973-7415)	4000 (1300-9999)	.63
PRBC, median (IQR), U	2 (0-10)	2 (0-10)	0 (0-14)	.63
Blood transfused, median (IQR), L[a]	0 (0-0)	0 (0-0)	0 (0-0)	<.001
INR, median (IQR)	1.2 (1.0-1.5)	1.2 (1.0-1.4)	1.4 (1.1-2.2)	.03
Total GCS score, median (IQR)	6 (3-15)	6 (3-15)	3 (3-7)	.06
Time from injury to LRMC arrival, median (IQR), h	38.0 (25.3-50.3)	38.3 (25.3-50.4)	31.9 (26.3-46.3)	.45

Abbreviations: GCS, Glasgow Coma Scale; INR, international normalized ratio; IQR, interquartile range; ISS, Injury Severity Score; LRMC, Landstuhl Regional Medical Center; PRBC, packed red blood cells; SBP, systolic blood pressure.

SI conversion factors: To convert base to millimoles per liter, multiply by 1.0; hematocrit to proportions of 1, multiply by 0.01.

[a] At least 75% of each group did not receive a transfusion, reflected in the median values. If we restrict the analysis to the individuals who underwent transfusion, the difference in volume between decedents (who were few in number) and survivors is statistically significant.

Table 3. Logistic Regression Analysis of Mortality Determinants

	Univariate		Multivariate[a]	
Variable	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Evacuation time, h	0.99 (0.87-1.01)	.34	NA	NA
ISS	1.06 (1.04-1.08)	<.001	1.05 (1.02-1.09)	<.001
Crystalloid volume	1.00 (1.00-1.00)	.27	NA	NA
PRBC	1.02 (0.99-1.05)	.28	NA	NA
Whole blood transfused	1.09 (1.03-1.16)	.003	1.21 (1.10-1.32)	<.001
SBP	0.99 (0.97-1.00)	.06	NA	NA
Heart rate	1.00 (0.98-1.01)	.72	NA	NA
Base deficit	0.88 (0.82-0.95)	<.001	NA	NA
INR	2.81 (1.48-5.34)	.002	2.22 (1.01-4.87)	.047
Hematocrit level	1.03 (0.98-1.09)	.23	NA	NA
Total GCS score	0.92 (0.84-1.00)	.052	NA	NA

Abbreviations: GCS, Glasgow Coma Scale; INR, international normalized ratio; ISS, Injury Severity Score; NA, not applicable; OR, odds ratio; PRBC, packed red blood cells; SBP, systolic blood pressure.

[a] Stepwise logistic regression analysis based on all variables with univariate $P \leq .15$.

day mortality for this group of patients transported by CCATT was 2.1%. We found no differences in survivorship with respect to race, branch of the military, age, or the number of intermediate stops between the location of injury and arrival at LRMC.

Mortality en route was less than 0.02%. Precise determination of mortality en route was complicated by the military requirement that death be declared only at a ground station with a precise geographical location. The determination was further complicated by the observation that nearly all deaths en route displayed severe or lethal central nervous system Injury Severity Scores (ISS scores of 5 or 6). Many of these casualties had already been declared brain-dead in theater. Transport of these casualties for family and/or consideration of organ donation was often undertaken.

To evaluate the possible determinants of mortality, we compared survivors and nonsurvivors using the χ^2 test, unpaired *t* test, and nonparametric Wilcoxon rank sum test. **Table 2** shows statistically significant differences between survivors and decedents with respect to ISS, cumulative volume of blood transfused among those who received a transfusion, worst base deficit, and worst international normalized ratio.

We found no statistically significant difference between survivors at 30 days and decedents with respect to time from injury to arrival at LRMC.

We further analyzed the effect of injury characteristics on mortality by application of logistic regression analysis (**Table 3**). In univariate logistic regression, ISS, cumulative units of whole blood transfused, worst base deficit, worst international normalized ratio, and worst Glasgow Coma Scale score were statistically significant predictors of mortality. Total time from injury to arrival at LRMC was not statistically significant. We then completed a multivariate logistic regression analysis to gauge the joint effect of these significant variables. In this multivariate analysis model, the following 3 predictors were statistically significant: ISS, cumulative units of whole blood transfused, and worst international normalized ratio.

Discussion

The combat casualties of OIF and OEF provided the first wide-scale test of the concept and capabilities of the USAF's

CCATTs. During the course of 10 years, the form and function of CCATT transport would slowly and continually evolve in response to lessons learned and experience gained. One of the primary purposes of undertaking this study was our attempt to evaluate the maturity of the CCATT data capture system and to evaluate the opportunity to complete meaningful performance evaluation of the care process en route. The scope of this discussion will focus on the results of this study and the implications for the continued evolution of the USAF's CCATT process.

One of the most noteworthy findings of this inquiry is that 93% of all CCATT patients (representing the most grievously injured combat casualties of this conflict) arrived at LRMC within 72 hours of wounding. Equally remarkable is the finding that 98.5% of all critically wounded soldiers were at LRMC by the 96-hour mark. The documented success and attendant minimal mortality of movement of CCATT patients within hours of surgery represent a paradigm shift for trauma surgeons and trauma surgery doctrine. The overall 30-day mortality for all patients transported by CCATTs is 2.1%, and the transport mortality en route is well less than 1% despite the transport of significantly injured combat casualties (mean ISS, 23.7). This historically low mortality rate is a tribute to and reflection of the dedication of the entire chain of survival established by the military and its medical corps. The chain of survival begins with the medic providing care under fire and continues until the casualty is returned to home station, family, and community.

The fact that this CCATT patient cadre *could* be moved so rapidly was not, in fact, evidence that they *should* be moved this rapidly. A focus of this inquiry was to examine the evidence to support or refute the medical efficacy of rapid evacuation of significantly wounded combat casualties across continental distances within hours of their wounding. The results from this large 10-year study demonstrate that, as a single factor, time from wounding until time of arrival at the definitive care facility (LRMC) did not independently affect the outcome (mortality). The factors associated with increasing mortality in this combat casualty population (excluding devastating head injury) include cumulative whole blood volume transfused, elevated base deficit, coagulopathy, and ISS. These factors are in keeping with the severity of injury in this patient population as documented by the mean ISS of almost 24. The remarkably low mortality of this entire cohort (2.1%) is in keeping with that of other published reports from OIF/OEF and offers a validation of the initial concept of the role of CCATTs. This same observation is also a tribute to the dedication of the military medical corps and the aeromedical evacuation system functioning as components in the chain of survival for military personnel. The care process en route begins at the point of wounding and continues through the delivery of the patient to rehabilitation centers back in the United States. It is remarkable to note that the median time to arrival in Germany for this entire cohort was 38 hours. The Herculean effort required to make this possible is but a small repayment for the sacrifice and commitment of the young men and women who serve this country in our armed forces. The continued critical evaluation of the timing and outcome of movement of CCATT patients remains a priority of scientific investigation within the USAF. Basic science investigations are currently under way to develop a more complete understanding of the impacts (positive and negative) of rapid aeromedical evacuation of critically injured patients. Although faster is better may seem intuitively appealing, certain models of injury suggest that in particular injury patterns, a delay before exposure to the transport process is desirable.[14,15]

A second focus of this initiative was to evaluate the opportunity to combine the existing JTTS database on injured casualties with the CCATT patient population in a performance improvement initiative. The form and processes of data capture and the maturation of the JTTR were as much an evolutionary process as the continual development of CCATT tactics, policies, and procedures. During these years of conflict, the data set requested and successfully recorded by the JTTR became increasingly more robust and complete. Nonetheless, of the initial 2702 CCATT combat casualties identified by the GPMRC, only 975 records contained sufficiently complete data sets for comprehensive statistical analysis of the directed query (ie, time from initial wounding to arrival at LRMC). Most of the missing data points were from the earliest parts of the evacuation chain (time of wounding). Given the logistical and educational challenges to data capture in a fluid and rapidly moving combat environment, this result is not surprising. Data capture with pencil and paper in a small, far-forward combat support facility (level II) is challenging, to say the least. Taken from a different perspective, the amount of data successfully captured in a combat zone is a remarkable tribute to the efforts of the JTTS and its many trauma nurse coordinators, trauma team members, and directors deployed to theater. Future medical equipment initiatives (ie, monitors, transport team equipment, and medical record keeping) are focusing on automated electronic data capture to increase the efficacy of data capture in these far-forward and austere settings. Small, portable, robust data monitoring systems with full physiological data capture and patient demographics are currently being fielded in demonstration mode at a theater facility in Afghanistan (J.J., observation; November 2013).

Another notable aspect of this inquiry is its representation of a small addition to a significant body of peer-reviewed articles forwarded by the military medical community during the course of this conflict. The initial development of the JTTS is, in fact, a reflection of the very positive synergy of the lessons brought forward from the civilian trauma care system in the United States as applied to combat care. The medical operations of OIF/OEF represent the first large-scale conflict where lessons learned by the evolution of the ACS COT American trauma system were applied across the military continuum of care. This synergy has provided for nearly concurrent review of outcomes, successes, and opportunities for improvement. Peer review is completed internally (within the military medical corps) as well as in a collaborative fashion with civilian peers in the guise of peer-reviewed papers and podium presentations at major academic meetings. Lessons learned are exchanged between military and civilian trauma communities to the benefit of the wounded soldier and the civilian trauma patient in the United States.

The results presented herein represent a dynamic and fluid evolution of the tactics, procedures, and policies of the CCATTs as they underwent their first wide-scale test in combat. The initial years of combat casualty care (2001-2004) provided challenges with respect to an extremely fluid and varied context of operations. Medical facilities in theater were rapidly expanding and moving to follow the forward areas of combat. Initially deployed CCATTs were stationed outside the combat theater at LRMC (Germany) or Al Udeid Air Base (Qatar). The CCATTs would fly into theater onboard long-range cargo aircraft and assist in the stabilization and subsequent return transfer of patients. As the theater matured, more robust combat support facilities evolved along with limited ICU capabilities. Solutions were continually advanced and operational strategies modified to meet the changing needs of supporting the medical casualty streams from Iraq and Afghanistan. The challenge for the USAF and its CCATTs was to ensure that the level and intensity of care remained uninterrupted during the entire spectrum of care en route. In some cases this meant the provision of care for a shorter intratheater transport onboard C-130 cargo aircraft and missions lasting 1 to 2 hours. In most cases, it meant preparing and sustaining critical care during long transcontinental flights onboard the C-141 (retired in 2007), the C-17, or the KC-135. The typical casualty would be moved from theater sometime at or about the second or third day after surgery.

As the conflict continued, the USAF and US Army developed large level III hospitals at bases colocated with large airfields in Iraq and subsequently Afghanistan (Balad Air Base, Iraq, and Bagram Air Base, Afghanistan). These bases provided the necessary airlift opportunity for evacuation of the casualties with their attendant CCATTs. By 2005, CCATTs had been moved “downrange” and were deployed to these same level III facilities to prepare and facilitate the subsequent movement of stabilized, but not necessarily stable, combat casualties. This movement also provided the additional critical care capabilities of the CCATTs to augment the ICUs of the level III facilities.

By early 2005, combat and medical operations had reached a significant level of maturity. Rapid evacuation from the point of injury by rotary wing medical evacuation promptly delivered casualties within minutes to awaiting operating rooms at surgically capable facilities (level II or level III). As necessary, these casualties would be moved to the central air hubs with their colocated level III facilities in anticipation of evacuation to Germany. During this phase of operations, the length of time between stabilization surgery and subsequent CCATT transport out of theater progressively decreased. This multifactorial effect was the result of increasing experience, colocation of CCATTs at the major air hubs, and increasing casualty volume. Combat casualties underwent 1 or more surgical stabilization procedures within the first 12 hours of wounding as a matter of routine. The first procedure might occur at a forward operating base with a smaller level II facility followed by rapid evacuation to the larger, central level III combat support/theater hospital. Further surgery was undertaken as necessary at the level III facility and/or the patient was rapidly prepared by awaiting CCATTs for subsequent transcontinental transport to Germany. The CCATT mission of accompanying patients who were within hours of wounding and surgery provided the challenge and the opportunity to continue postoperative critical care and resuscitation, literally on the fly. The progressively shorter intervals from wounding to arrival in Germany offered the advantage of delivering the casualty an increasing level of medical sophistication in a much cleaner, resource-intensive, and controlled environment of care provided by the verified trauma center at LRMC.

Conclusions

The results of this study suggest that the CCATT process has proved itself to be an important component of the continuum of combat casualty care. The process of rapid movement of critically injured casualties within hours of their wounding appears to be effective, with minimal mortality incurred during movement (<0.02%) and an overall 30-day mortality of 2.1%. The selfless service and dedication of the countless hands that touch the wounded casualty during the care process en route are but a small debt of repayment for the service of our wounded warrior.

ARTICLE INFORMATION

Accepted for Publication: October 14, 2013.

Published Online: June 25, 2014. doi:10.1001/jamasurg.2014.621.

Author Affiliations: Department of Surgery, Nellis Air Force Base (AFB), University of Nevada, Las Vegas (Ingalls); Critical Care Program, Landsthul Regional Medical Center, Kaiserlautern, Germany (Zonies); Joint Trauma System, US Army Institute of Surgical Research, Ft Sam Houston, Texas (Bailey); Trauma Program, Landstuhl Regional Medical Center, Kaiserlautern, Germany (Martin); Headquarters Air Mobility Command, Scott AFB, Illinois (Iddins); Office of the Surgeon General, US Department of Health and Human Services, Washington, DC (Carlton); Division of Trauma and Critical Care, Department of Surgery, University of Cincinnati, Cinncinnati, Ohio (Hanseman, Branson, Dorlac, Johannigman).

Author Contributions: Drs Hanseman and Johannigman had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Zonies, Martin, Carlton, Hanseman, Branson, Johannigman.
Acquisition, analysis, or interpretation of data: Ingalls, Zonies, Bailey, Iddins, Hanseman, Branson, Dorlac, Johannigman.
Drafting of the manuscript: Iddins, Carlton, Branson, Johannigman.
Critical revision of the manuscript for important intellectual content: Ingalls, Zonies, Bailey, Martin, Iddins, Hanseman, Branson, Dorlac, Johannigman.
Statistical analysis: Zonies, Hanseman.
Obtained funding: Johannigman.
Administrative, technical, or material support: Ingalls, Zonies, Bailey, Martin, Iddins, Branson, Dorlac.
Study supervision: Carlton, Branson, Johannigman.

Conflict of Interest Disclosures: None reported.

Funding/Support: This study was supported by internal funding from the Department of Surgery, University of Cincinnati.

Role of the Sponsor: The funding source had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

REFERENCES

1. Pruitt BA Jr. Combat casualty care and surgical progress. *Ann Surg*. 2006;243(6):715-729.

2. Committee on Trauma, American College of Surgeons. *Resources for Optimal Care of the Injured Patient 2006.* Chicago, IL: American College of Surgeons; January 2007.

3. General Accountability Office. *Operation Desert Storm: Full Army Medical Capability Not Achieved.* Washington, DC: GAO; August 1992. Report No. GAO/NSIAD-92-175.

4. General Accountability Office. *Operation Desert Storm: Problems With Air Force Medical Readiness.* Washington, DC: GAO; December 1993. Letter Report No. GAO/NSIAD-94-58.

5. General Accountability Office. *Wartime Medical Care: DOD Is Addressing Capability Shortfalls, but Challenges Remain.* Washington, DC: GAO; September 1996. Report No. NSIAD-96-224.

6. US Army Institute of Surgical Research. Joint trauma system. http://www.usaisr.amedd.army.mil/joint_trauma_system.html. Accessed February 2, 2013.

7. Beninati W, Meyer MT, Carter TE. The critical care air transport program. *Crit Care Med*. 2008;36(7)(suppl):S370-S376.

8. Johannigman JA. Critical care aeromedical teams (CCAT): then, now and what's next. *J Trauma*. 2007;62(6)(suppl):S35.

9. Eastridge BJ, Jenkins D, Flaherty S, Schiller H, Holcomb JB. Trauma system development in a theater of war: experiences from Operation Iraqi Freedom and Operation Enduring Freedom. *J Trauma*. 2006;61(6):1366-1373.

10. Eastridge BJ, Wade CE, Spott MA, et al. Utilizing a trauma systems approach to benchmark and improve combat casualty care. *J Trauma*. 2010;69(suppl 1):S5-S9.

11. Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF. Understanding combat casualty care statistics. *J Trauma*. 2006;60(2):397-401.

12. DuBose JJ, Barmparas G, Inaba K, et al. Isolated severe traumatic brain injuries sustained during combat operations: demographics, mortality outcomes, and lessons to be learned from contrasts to civilian counterparts. *J Trauma*. 2011;70(1):11-18.

13. Eastridge BJ, Costanzo G, Jenkins D, et al. Impact of joint theater trauma system initiatives on battlefield injury outcomes. *Am J Surg*. 2009;198(6):852-857.

14. Goodman MD, Makley AT, Lentsch AB, et al. Traumatic brain injury and aeromedical evacuation: when is the brain fit to fly? *J Surg Res*. 2010;164(2):286-293.

15. Makley AT, Belizaire R, Campion EM, et al. Simulated aeromedical evacuation does not affect systemic inflammation or organ injury in a murine model of hemorrhagic shock. *Mil Med*. 2012;177(8):911-916.